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What Improves Environmental Performance?

Evidence from Mexican Industry

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Strengthened enforcement raises the price of pollution and provides an incentive to reduce it. A cost-effective complement to stricter enforcement is effective environmental management and training programs within plants.

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Summary findings

Using new survey evidence, Dasgupta, Hettige, and Wheeler analyze the effects of regulation, plant-level management policies, and plant and firm characteristics on environmental performance in Mexican factories. They focus especially on management policies: the degree of effort to improve environmental performance and the type of management strategy adopted.

They index effort with two variables: adoption of ISO 14000-type procedures for pollution management and use of plant personnel for environmental inspection and control. Proxies for strategic orientation are two indices of mainstreaming: assigning environmental responsibilities to general managers instead of specialized environmental managers, and providing environmental training for all plant employees, not just specialists.

Detailed survey data let them test the performance impact of such factors as ownership, scale, sector, trade and other business relationships, local regulatory enforcement, local community pressure, management education and experience, and workers' general education. Their findings:

Process is important. Plants that institute ISO 14000-type internal management procedures show superior environmental performance.

Mainstreaming works. Environmental training for all plant personnel is more effective than developing a cadre of environmental specialists, and assigning environmental tasks to general managers is more effective than using special environmental managers.

Regulatory pressure works. Plants that have experienced regulatory inspections and enforcement are significantly cleaner than those that have not.

Public scrutiny promotes stronger environmental policies. Publicly traded Mexican firms are significantly cleaner than privately held firms.

Size matters. Large plants in multiplant firms are much more likely to adopt policies that improve environmental performance.

OECD influences do not matter. It is generally assumed that plants linked to OECD economies show superior environmental performance, but they find no evidence that OECD links — including multinational ownership, trade, management training, or management experience — affect environmental performance.

New technology is not significantly cleaner. They find no evidence that plants with newer equipment perform better environmentally (once other factors are accounted for).

Education promotes clean production. Plants with more highly educated workers show significantly better environmental management efforts and performance.

This paper — a product of the Development Research Group — is part of a larger effort in the group to understand the determinants of environmental performance in developing countries. The study was funded by the Bank's Research Support Budget under the research project "The Economics of Industrial Pollution Control in Developing Countries" (RPO 680-20). Copies of this paper are available free from the World Bank, 1818 H Street NW, Washington, DC 20433. Please contact David Wheeler, room MC2-529, telephone 202-473-3401, fax 202-522-3230, Internet address dwheeler1@worldbank.org. January 1998. (24 pages)

What Improves Environmental Performance? Evidence from Mexican Industry

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EXECUTIVE SUMMARY

This paper uses new survey evidence to analyze the effects of regulation, plant-level management policies, and plant/firm characteristics on the environmental performance of Mexican factories. We focus particularly on management policies: the degree of effort to improve environmental performance, and the type of management strategy which is adopted. Effort is indexed by two variables: adoption of ISO 14000-type procedures for pollution management,[1] and use of plant personnel for environmental inspection and control. Strategic orientation is proxied by two indices of 'mainstreaming:' assignment of environmental responsibilities to general managers, instead of specialized environmental managers; and general environmental training for plant employees, as opposed to training for specialists only. Our detailed survey data also enable us to test the performance impact of many other factors, including ownership, scale, sector, trade and other business relationships, local regulatory enforcement, local community pressure, management education and experience, and workers' general education.

Recognizing that plant-level management policies and environmental performance are simultaneously determined, the paper uses two-stage least squares for econometric estimation. In the first-stage equations, the four management policy indices are regressed on exogenous measures of regulation and the characteristics of plants, firms and markets. The first-stage results are used to instrument the management indices in the second-stage regression, which measures their impact on actual performance, along with the effects of workers' education and the cost of pollution control.

The implications of our results can be summarized as follows:

(1) **Process is important.** Plants which institute ISO 14000-type internal management procedures exhibit superior environmental performance.
(2) **Mainstreaming works**. Environmental training for all plant personnel is more effective than developing a cadre of environmental specialists; assigning environmental tasks to general managers is more effective than using special environmental managers.
(3) **Regulatory pressure works.** Plants which have experienced regulatory inspections and enforcement are significantly cleaner than their counterparts.
(4) **Public scrutiny promotes stronger environmental policies.** Publicly-traded Mexican firms are significantly cleaner than their privately-held counterparts
(5) **Size matters.** Large plants in multi-plant firms are much more likely to adopt policies which improve environmental performance.
(6) **OECD influences don't matter.** Analyses of pollution control in developing countries generally assume that plants linked to the OECD economies have superior environmental performance. However, we do not find a significant role for <u>any</u> OECD

[1] See Appendix 2 for a description of ISO 14000 environmental management standards.

linkage: multinational ownership, trade, management training, or management experience.

(7) **New technology isn't significantly cleaner**. We find no evidence that plants with newer equipment have better environmental performance, once other factors are accounted for.

(8) **Education promotes clean production.** Plants with more highly-educated workers have significantly greater environmental management effort and better performance.

Our results have some interesting implications for the World Bank and other development assistance institutions. The significance of our regulatory variables underscores the importance of strengthened enforcement, which has been a traditional focus of technical assistance projects. Stricter enforcement raises the *price of pollution* and provides an important incentive for pollution reduction. However, our results also highlight the potential of programs which promote more effective environmental management and training within plants. Such programs can increase the *elasticity of industry's response* to regulation, and may in some cases provide very cost-effective complements to stricter enforcement.

1. Introduction

Researchers in economics and management typically differ in their treatment of management decisions. Assuming that firms optimize with known production sets (including management techniques), economists prefer to analyze responses to exogenous changes in markets, regulations and other variables. The conventional, if generally unspoken, view is that management practices are endogenous. Some management researchers, on the other hand, are comfortable with the assumption that managers have incomplete knowledge of production sets and techniques for optimization. This assumption validates empirical studies which relate management choices to differences in profitability.

Although we are economists, we adopt the management research perspective in this paper because the assumption of incomplete information seems appropriate. For plant and firm managers in developing countries, improved environmental performance implies experimentation with new production sets. In Mexico, for example, serious environmental regulation is largely a phenomenon of the 1990's. Both regulators and businesses are still adjusting to the environmental era, and there is considerable uncertainty about the relative effectiveness of alternative approaches to regulatory policy and plant-level environmental management.

Using recent survey evidence from Mexico, this paper analyzes the relationships linking management and environmental performance in a large sample of industrial facilities. We focus on two questions. First, why does plant-level environmental performance in developing countries vary so widely when regulation is weak? Conventional theory would suggest little or no pollution control effort when the 'price of pollution' is very low. However, many factories in developing countries have already adopted significant pollution control measures. Recent work on industrial pollution in Asia has suggested the importance of three factors:[2] **formal regulation** (where it exists); **informal regulation**, or community pressure; and **plant and firm characteristics** which affect both the cost of abatement and the incentive to abate. In Asia, the characteristics which best explain variations in environmental performance are plant size (a plus, because of public visibility and scale economies in abatement); government ownership (a distinct minus, because government facilities are less efficient and typically shielded from formal or informal regulatory pressure); and production sector (because of generic variations in process technologies and abatement costs). Contrary to the conventional view, this research has not found any evidence that multinational ownership has a significant effect on environmental performance. However, there is strong evidence that local community pressure (informal regulation) has an impact.

While the Asian results provide some initial insights, data limitations have prevented a comprehensive analysis. Important but unanswered questions include:

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[2] See Pargal and Wheeler, 1996; Hettige, et. al., 1996; Hartman, et. al., 1996; Wang and Wheeler, 1996.

1. Are plants with newer equipment more likely to comply with regulations, both because newer technologies are cleaner and because end-of-pipe abatement is less costly for plants which use newer processes?
2. Are plants which export heavily to the OECD affected by environmentalist concerns in their client countries?
3. Are plants cleaner if they have managers whose training and/or experience has been in OECD countries?
4. Are firms whose shares are publicly traded more sensitive to environmental issues, and more likely to seek improved environmental performance, than privately-held firms?
5. Do scale economies in pollution control originate at the firm level, as well as the plant level?
6. Do plants with more human capital control pollution more effectively?

Our second question is: *How* do manufacturing facilities achieve better environmental performance? We can address this question because the Mexican industry survey includes detailed questions about environmental management and training practices. In the paper, we investigate interplant differences in these practices and their impact on environmental performance.

Our empirical assessment of internal policies recognizes an inevitable simultaneity problem: Positive correlations between superior environmental performance and indices of environmental management do not imply causal roles for the latter. Firms will almost certainly change their environmental management practices when optimal pollution abatement levels are altered by exogenous changes in regulations or prices.

We use two-stage least squares to address this simultaneity problem. In the first-stage equations, we regress internal management indices on exogenous determinants of pollution control activity. Our management indices capture both relative effort to improve performance and the type of strategy adopted by the plant. Effort is indexed by two variables: degree of adoption of ISO 14000-type procedures for pollution management; and expanded use of plant personnel for environmental inspection and control. Strategic orientation is captured by two measures of 'mainstreaming' environmental concerns: assignment of environmental responsibilities to general managers, rather than specialized environmental managers; and general environmental training for plant employees, as opposed to training focused on environmental specialists.

Our detailed survey data enable us to test the effect of many exogenous factors on management effort and strategic orientation. These include plant and firm scale, ownership, human resource quality, trade relationships, OECD training and experience of plant managers, experience of formal regulation in previous years, and degree of informal regulation by local communities. The results of the first-stage equations are, of course, interesting in themselves. They also enable us to construct instrumented versions of the management indices for the second-stage equation. The dependent variable in this equation is a measure of compliance with Mexican environmental regulations. Righthand variables include the four instrumented policy indices, a measure of general employee

education, and proxies for pollution abatement costs (sector, scale and technology vintage).

We believe that this two-stage analysis can provide useful information for both public and private managers in developing countries. For private managers, it can help reduce uncertainty about appropriate strategies for improving environmental performance. For public managers, it can help identify the most important sources of leverage to reduce excessive pollution. By identifying effective internal management options, it may also suggest new possibilities for cost-effective intervention. Economists have traditionally argued that regulators should use market-based instruments whenever possible, leaving industry to determine appropriate ways of adjusting to stricter regulation. We support this proposition, but our results suggest a possible extension: By increasing the *elasticity* of firms' response to new incentives, appropriate technical assistance for improved internal management may be a cost-effective adjunct to market-based regulation.

The rest of the paper is organized as follows. Section 2 introduces Mexico's pollution control system, and Section 3 describes the survey which has been used for our analysis. The analytical approach and estimating equations are developed in Section 4; results are discussed in Section 5; and Section 6 explores the implications with a simulation exercise. Section 7 concludes the paper.

2. Industrial Pollution and Regulation in Mexico

During the past forty years, Mexico has built one of the largest industrial economies in the developing world. Until recently, however, environmental regulation has received scant attention. The result for Mexico City has been air pollution which is among the worst in the world, and other cities are also suffering from excessive pollution (Hettige, et. al., 1996). Table 1 provides recent emissions estimates for Mexico's urban regions.

At the national level, an institutional response to this problem began in the late 1980's and has accelerated during the past few years. In its first phase of development, the national regulatory system has had two prominent characteristics: an emphasis on command-and-control regulation, and a multi-institutional approach to monitoring and enforcement. Under command-and-control regulation, the environmental performance of polluters is evaluated according to compliance with numerous licenses and permits issued to each plant.

Table 1: Pollution from Industrial Sources in Urban Mexico, 1994 (tons/year)

	Pollution Sources	TSP[a]	SO_2[b]	CO[c]	NOx[d]	HC[e]	Total
Total	6,345	143,024	1,161,231	203,142	313,060	145,508	1,965,965
Urban Area							
Tula-Vito-Apaxco	13	21,503	339,763	2,787	66,270	12,540	442,863
Manzanillo, Col.	11	18,881	207,045	2,292	52,296	414	280,928
Toluca-Lerma, Edo. Mex.	67	13,704	203,170	2,006	42,779	1,274	262,933
Salamanca, Gto.	49	11,391	117,675	3,565	21,930	4,073	158,634
Tijuana, B.C.	114	3,053	11,749	117,552	6,032	231	138,617
Coatzacoalcos-Minatitlán	78	9,944	5,818	25,053	35,125	58,479	134,419
Tampico-Altamira	14	5,876	66,323	824	8,876	30,660	112,559
ZMVM	4,623	6,358	26,051	8,693	31,520	33,099	105,721
Torreón, Coah.	94	4,585	59,092	8,052	639	178	72,546
Monterrey, N.L.	85	9,724	22,360	2,164	8,375	115	42,738
La Paz, B.C.S.	25	3,038	31,128	267	6,007	45	40,485
Mérida, Yuc.	42	2,497	28,932	1,057	7,806	79	40,371
Cd. Juárez, Chih.	135	4,968	5,751	17,199	9,160	1,195	38,273
Guadalajara, Jal.	423	15,045	10,634	1,624	3,184	49	30,536
Other cities	572	12,457	25,740	10,007	13,061	3,077	64,342

[a] Total Suspended Particulates; [b] Sulfur Dioxide; [c] Carbon Monoxide; [d] Nitrogen Oxides; [e] Hydrocarbons

Source: SEMARNAP

The second prominent characteristic of Mexican environmental management has been multi-institutional administration. Different aspects of industrial pollution control have been the responsibility of different agencies within the *Secretaría del Medio Ambiente, Recursos Naturales y Pesca* (SEMARNAP). The principal units are the *Instituto Nacional de Ecología* (INE), responsible for monitoring air and toxic emissions; *Comisión Nacional del Agua* (CNA), with similar responsibility for water emissions; and *Procuraduría Federal de Protección al Ambiente* (PROFEPA), which is charged with factory inspections and enforcement of all pollution regulations. During the 1990's, PROFEPA has expanded its activities from a few inspections per year to several thousand.

Mexican environmental policy continues to evolve rapidly, reflecting rising consciousness of pollution problems and Mexico's higher international profile (e.g., negotiations to enter NAFTA and the OECD). In April 1997, President Zedillo introduced a new approach to pollution control in Mexico, based in part on rapid development and implementation of the *Sistema Integrado de Regulación Directa y Gestión Ambiental de la Industria* (SIRG). The SIRG is intended to promote Mexico's interest in both international competitiveness and strong environmental protection. It will integrate regulation of emissions to air, ground and water; stress cost-effective regulatory instruments; permit much broader public access to environmental information; and operate from an integrated information system which will employ all the data resources of SEMARNAP.

For the purposes of this paper, two aspects of Mexico's recent pollution control experience are most important. First, the system is quite new. Many Mexican factories have not yet been inspected, although PROFEPA's activities are widely known. Second, business managers in Mexico now acknowledge that they will have to respond to stricter environmental standards. Our survey of Mexican industry therefore provides a snapshot of an industrial system in transition. Faced with credible evidence of the government's intent to regulate more strictly, Mexican firms have begun experimenting with new approaches to environmental management and training.

3. The National Survey of Industrial Polluters

The data used for this paper were produced by a large survey of Mexican manufacturers carried out in the fall of 1995. The survey focused on four sectors which are estimated to generate between 75% and 95% of Mexico's total industrial pollution: Food, chemicals, non-metallic minerals, and metals. Confidential, in-depth interviews were conducted at 236 facilities, chosen to represent Mexican factories in a set of categories defined by sector, size class, and location. Tables 2 and 3 provide information on the distribution of plants surveyed. Summary information on other variables can be found in Appendix 1.

Table 2: Sectoral and Size-Class Distribution of Plants Surveyed

Size[a]/Sector	Food	Chemicals	Non-Metallic Minerals	Metals
Large	21	18	12	20
Medium	22	21	12	18
Small	19	23	27	23

[a] Size classes are defined by employment ranges as follows: Small (16 -100 employees); Medium (100 - 250); Large (250 +)

Table 3: Regional and Sectoral Distribution of Plants Surveyed

Region[a]/Sector	Food	Chemicals	Non-Metallic Minerals	Metals
Medium City	21	20	18	21
Industry Corridor[b]	19	20	9	21
Large City	22	22	24	19

[a] An industrial area which extends between two urban regions

The survey was designed by a World Bank team which included the authors. It was conducted by the Monterrey Institute of Technology (MIT), with the explicit support of Mexico's National Environment Ministry (SEMARNAP) and the Mexican National Association of Industries. To minimize reporting bias, the survey was conducted only after agreement by all sponsors (the Government, the Bank and the Industries Association) that

the MIT team would not reveal the identity of the plants surveyed or the respondents within the plants.

The survey provides very detailed information about environmental performance and its determinants, including plant, firm and market characteristics; sources of environmental information; the quality and costliness of relationships with regulators; the cost of pollution control; and the measures taken by plant management to improve performance.

Our analysis relies solely on self-reported environmental performance, since we had no access to independently-audited data on pollution and regulatory compliance. Is self-assessed performance a credible measure? Useful evidence is provided by Table 4, which summarizes the respondents' overall assessment of their facilities' compliance with Mexican regulations.

Table 4: Self-Assessed Environmental Performance

Environmental Performance	Number of Plants	% of Total
Excellent: Far more than necessary for compliance	23	10
Good: Almost always in compliance	84	38
Fair: Occasionally compliant	99	44
Poor: Never in compliance	10	4
Very Poor: Far below compliance; very damaging	8	4

With confidentiality reasonably well-assured, 52% of survey respondents replied that their plants were not in compliance with regulations. Only 10% rated their facilities as Excellent, and approximately the same number as Poor or Very Poor. We have no benchmarks, so we can only make an educated guess about the degree of upward bias in this self-assessment. Suggestive evidence is provided by recent research on Indonesia, a country with similar regulations but much weaker monitoring and enforcement. Independent auditing of a large sample of Indonesian plants has shown that approximately 64% are non-compliant (Afsah, et. al., 1996), with 3% in the 'extremely damaging' category. This evidence suggests that the degree of upward bias in the Mexican self-assessment may not be large. In any case, our analysis focuses on relative, not absolute, performance. Independent assessment of conditions in the surveyed plants by the MIT team indicated a high correlation between self-assessment and observable conditions.

4. Modeling Environmental Performance

In the short run, plant managers typically respond to stricter regulation with some investment in end-of-pipe abatement equipment. They also begin a long-run process of experimentation and adaptation, in which products and processes are re-assessed in the search for new optimum arrangements. Formally, this response can be captured by extending the standard KLEM production frontier into a new dimension: 'use of environmental services,' or pollution (P). In the KLEMP model, stricter regulation imposes a non-zero pollution price (either implicitly, through enforcement of standards, or explicitly, through the collection of pollution charges or imposition of tradable permit systems). Faced with a new set of relative input prices, profit-maximizing firms reveal a new set of input demand equations, including one for environmental demand.[3]

The environmental demand function differs from the others in one important respect: The incremental cost of pollution to the firm is an expected value, not a set price. It is influenced by many variables, including stochastic enforcement actions, variable financial penalties, reputational damage, and the uncertain cost of extensive negotiations with regulators, local communities, and other environmental stakeholders. Plants and firms with different characteristics will assess enforcement probabilities and expected costs in different ways. Although much empirical research remains to be done, economic logic does suggest some hypotheses about the determinants of plant and firm responses.

Determinants of Environmental Effort

Scale: Improving environmental performance requires some fixed investment and the application of specialized skills. Large facilities should therefore find it less costly at the margin to undertake performance-improving measures. At a higher organizational level, the same argument should hold true for multi-plant firms: Specialized resources can be spread over more units, allowing for more ambitious environmental initiatives. Scale should also work through the 'visibility effect' (see Pargal and Wheeler, 1996): Larger polluters are more detectable by surrounding communities, and may well be under stronger pressure to abate. Thus, scale may increase the incentive to abate as well as the elasticity of response. Both factors should push factories toward more pollution control effort.

Public Information: Recent research in North America, Latin America and Asia (Laplante, et. al., 1994, 1997) has shown that environmental performance affects stock prices in both developed and developing countries. Publicly-traded firms whose good performance is publicized receive premia in the market; bad performers are discounted. Since this provides an additional incentive to control pollution, we would expect publicly-traded firms to have stronger environmental management than their privately-held counterparts.

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[3] For an extended discussion see Pargal and Wheeler (1996).

OECD Linkages: It is plausible to suppose that industrial facilities will have stronger environmental management if they are linked to the OECD economies through ownership, trade, and professional relationships. To minimize internal transactions costs, multinationals may use OECD-standard environmental management practices in developing countries. The rapid growth of green labeling in North America and Western Europe may pressure developing-country exporters toward greater environmental effort. Local managers trained in OECD business or technical schools, or with OECD operations experience, may adopt practices which reflect the environmental standards of their host countries.

Education: More highly-educated workers and managers should respond more efficiently to new incentives, so we would expect more environmental effort from factories with greater human resources.

Regulation: Since 1990, PROFEPA has rapidly expanded its inspection and enforcement program. A significant proportion of Mexican factories have now been inspected at least once. In addition, local authorities have inspection and enforcement programs in some urban areas. Recent research for the U.S. (Magat and Viscusi, 1990) and Canada (Laplante and Rilstone, 1996) has suggested that inspections have a significant impact on environmental management, even in cases where factories are in formal compliance with regulations. If the regulatory system is working in Mexico, we would expect to observe the same impact.

Technology vintage: More recent vintages (particularly imported equipment) should reflect stricter environmental regulation by incorporating environment-saving innovations. In addition, end-of-pipe pollution abatement equipment is generally less costly to install when it is combined with more recent technologies. Since better environmental performance should cost less in newer plants, we might expect to observe more environmental effort in such facilities.

Sector: Industry sectors vary significantly in pollution intensity (pollution per unit of output) because of differences in abatement costs (Dasgupta, et. al., 1996; Hartman, et. al., 1997). Faced with identical expected penalties for pollution, we would expect sectors with lower abatement costs to exhibit greater environmental effort.

Management Options and Environmental Performance

Since Mexico has only recently entered the environmental era, it does not seem realistic to assume that Mexican firms are fully-informed about the profitability of alternative strategies for pollution control. Under these conditions, we believe that new information can be generated by studying the impact of management on environmental performance. We use the survey information to define two indices of management effort in this context: adoption of ISO 14000-type environmental management procedures; and expanded use of personnel for environmental inspection and control. To study the effect of alternative strategies, we also define two indices of 'mainstreaming:' assignment of environmental

responsibilities to general managers, rather than specialized environmental managers; and general environmental training for plant employees, as opposed to training focused on environmental specialists.

The rationale for one of our effort indices seems clear: Expanded use of personnel for environmental inspection and control reflects the standard logic of resource reallocation when relative prices change. However, the other indices require more explanation.

ISO 14000 Sequence: Why should a 'workbook' approach to environmental management yield better performance? In general, workbook exercises will improve overall understanding and performance only if they induce appropriate learning. In the case of ISO 14000, the basic 'exercises' are defined as follows:[4]

1. An initial review by management to identify environmental issues of concern (e.g. excessive use of polluting inputs; the potential for a serious environmental accident);
2. Establishment of priorities for action, taking into account factors such as local environmental regulations and potential costs;
3. Establishment of an environmental policy statement, to be signed by the CEO;
4. Development of performance targets based on the policy statement (e.g. reduction of heavy metals emissions by 50% by some future date);
5. Implementation of an environmental management system as part of reaching the performance targets;
6. Implementation review; performance measurement.

Following the ISO 14000 sequence will not, of course, guarantee any improvement in environmental performance. However, it seems likely that plants which complete these steps will be informed, organized, and motivated in ways which distinguish them from other facilities. As Table 5 shows, the factories in our sample vary widely in their adoption of such practices.

[4] See Appendix 2 for a more detailed discussion.

Table 5: Adoption of ISO 14000 Procedures

Adoption Score	Number of Plants	Percent
$S \leq 25$	111	47.0
$25 < S \leq 50$	45	19.1
$50 < S \leq 75$	38	16.1
$75 < S \leq 100$	42	17.8

Mainstreaming vs. Specialization: From a theoretical perspective, neither mainstreaming nor specialization is clearly optimal under all conditions. The argument for specialized training and management seems strongest for cases where environmental problems are technically complex, concentrated at a few points, and separated from standard production processes. However, in real-world cases this potential advantage may never be greater than the benefits from mainstreaming. Table 6 shows that our sample plants are pursuing different options: Only 6% have specialized environmental managers, while 67% have specialized environmental training. It is possible to reconcile these data with a model of optimization, but it seems more plausible to regard Table 6 as a snapshot of experimentation in a transitional era. We will return to this issue in our discussion of the results.

Table 6: Mainstreaming vs. Specialization

	Yes	%	No	%
Environmental training for non-environmental workers?	76	32.6	157	67.4
Environment manager also has other responsibilities?	211	93.8	14	6.2

Econometric Estimation

The first stage of our analysis attempts to identify the major determinants of environmental effort and orientation toward mainstreaming. In four regressions, we test the relative effects of sector, scale, ownership, OECD links, education, prior regulation, and technology vintage. The regressions are specified in the following variables:

MGT = f (SIZE, TECH, PUBLIC, MULTINAT, OECD, MEXICO, MULTIDIV, EMPSEC, EMPHIGH, MGTSEC, OTHEXP, ENFORCE, RULES, INFORMAL, CONVENIO, FOOD, CHEM, METAL),

where the four MGT indices are defined as follows:

EMS: Steps completed in ISO 14000 Environmental Management System development (See Appendix 2)
LABOR: Significant assignment of workers to environmental work? (1 if yes)
MGT: Environmental manager also assigned to other work? (1 if yes)
TRAINING: Is environmental training given to non-environmental workers? (1 if yes)

The righthand variables are:

SIZE: Sequential categorical variable (1 if employment 16-100; 2 if 100-250; 3 if greater than 250)
TECH: Proportion of equipment acquired since 1990
PUBLIC: Proportion of the firm which is publicly traded
MULTINAT: Dummy variable (1 if multinational; 0 otherwise)
OECD: Share of plant's shipments going to OECD countries
MEXICO: Share of plant's shipments going to Mexican destinations
MULTIDIV: Whether the plant is part of a multidivisional firm (1 if yes)
EMPSEC: Proportion of employees with secondary school education
EMPHIGH: Proportion of employees with post-secondary education
MGTSEC: Is secondary education the highest attained by the plant's senior manager? (1 if yes)
OTHEXP: Has the plant's senior manager had education or experience abroad? (1 if yes)
ENFORCE: Has the plant been subject to a regulatory inspection? (1 if yes)
RULES: Degree of influence of regulatory policies (0 (None) to 5 (High))
INFORMAL: Degree of influence of neighbors and community (0 (None) to 5 (High))
CONVENIO: Has the plant signed an environmental convenio with the local community? (1 if yes)
FOOD, CHEM, METAL: Dummy variables for the Food, Chemical and Metals sectors.

Our second-stage analysis studies the relative impact of environmental effort and mainstreaming on environmental performance. A priori, we would expect better performance in plants which use more personnel for environmental monitoring and inspection. However, we are agnostic about whether adherence to a set of environmental management routines can, in itself, produce better performance. We have good information about the degree to which plants have implemented ISO 14000-type procedures, so we are able to test this proposition directly.

We are also interested in the impact of alternative strategies for training and assignment of responsibilities for environmental management. We use our information to investigate two questions about mainstreaming: First, for equivalent resources, is environmental performance improved more by training a specialized cadre of environmental workers, or by spreading the training resources across all workers? Second, is it better to assign

managers to the specialized task of environmental improvement, or is it better for line managers to assume environmental management as one of several tasks? In each case, it is possible to construct arguments for and against these propositions. In the second-stage analysis, we estimate a probit equation which relates self-assessed compliance with environmental regulations to the four management indices, general worker education, and proxies for abatement costs. The four management policy variables (EMS, LABOR, MGT, TRAINING) are instrumented using the first-stage results. The probit equation is specified in the following variables:

COMPLY = f (EMS, LABOR, MGT, TRAINING, EMPHIGH, SIZE, TECH, FOOD, CHEM, METAL)

where **COMPLY** = 1 if self-assessed performance (Table 4) is in categories 1 or 2;
0 otherwise

5. Results

Management Indices

Table 7 provides a summary of the first-stage estimates. We have included only variables which are significant at conventional confidence levels. Our most striking result is a negative one: Most of the variables with some plausible claim to influence on environment effort have no significant effect. These include all variables indexing *OECD linkages* (through ownership, trade, training or management experience), *technology vintage*, and *indirect community pressure* (other than through formal regulatory actions).

The absence of any significance for foreign ties contradicts the conventional wisdom, but it is consistent with results which we have obtained from analyses of plant-level environmental performance in Asia. We also find no significant differences for factories with more modern technology. This first-stage result has no strong implication for ultimate environmental performance: Modern technology might actually induce *less* environmental effort, if modern plants run cleaner anyway. However, as we will see below, technological neutrality is pervasive in our results. Surprisingly, more modern technology seems to make no difference for environmental performance once we control for other variables.

Finally, we are interested to note that plants which report greater indirect community pressure (as opposed to formal regulatory pressure) don't exhibit greater environmental effort than their counterparts. Recent work on Southeast Asia (Pargal and Wheeler, 1996, Hartman, Huq and Wheeler, 1996) has suggested that local community characteristics such as income and education have a significant effect on the environmental performance of neighboring factories. Plentiful anecdotal evidence suggests that richer, more educated communities can pressure factories to control pollution. However, the Asian research has not been able to distinguish between local actions which are 'formal' (i.e. part of local regulatory procedures) and 'informal' (e.g., negotiations with community groups). The

Mexican data are significantly more detailed, and suggest that local influence is working principally through local regulation.

Table 7: First-Stage Regression Results

Variable	EMS	LABOR	MGT	TRAINING
SIZE	14.553 (5.81)[a]		-0.685 (3.082)	0.305 (2.586)
PUBLIC		0.0052 (2.433)		0.0094 (4.586)
MULTIDIV	15.953 (3.98)			
EMPHIGH	0.215 (3.349)	0.0075 (1.972)		
RULES	4.367 (3.674)		-0.307 (1.740)	
ENFORCE		0.855 (2.919)		
CONSTANT	-20.810 (3.485)	-1.187 (3.829)	4.424 (4.368)	
Adj. R^2	.40	.10	.18	.14
Observations	209	178	225	206

[a] t-statistics in parentheses

Variables which <u>are</u> significantly associated with management effort include *scale (at both plant and firm levels)*, *regulation and enforcement*; *general worker education*; and *public trading of the firm's stock*. The scale results are consistent with a lowering of unit costs as lumpy environmental resources are spread across more units of activity. Regulation and enforcement by national and local authorities seem to be making a difference in Mexico. We attribute the significance of worker education to greater efficiency in responding to new environmental incentives. Publicly-traded firms exhibit greater effort, presumably because public information provides an additional incentive to improve environmental performance.

An even smaller set of variables is significantly associated with orientation toward mainstreaming. Scale has countervailing effects: Larger plants in multi-plant firms have significantly more environmental training for non-environmental workers, but larger plants also tend to assign environmental responsibility to specialized managers. There is some evidence that plants with prior experience of enforcement have more specialized environmental managers, but this is not a strong result.

Environmental Performance

Table 8 summarizes the results for our second-stage compliance equation. Sample observations are almost evenly split between compliant (48%) and non-compliant (52%) facilities. The complete compliance equation includes the four environmental management indices; the educational level of workers in the factory (to control for differential efficiency in achieving compliance); and three variables which serve as instruments for unobservable abatement costs: plant size, technology vintage, and sector.[5] In Table 8, we include only variables which are significant in at least some of our regression runs.

Table 8: Second-Stage Probit Results

Variable	COMPLY
EMS (IV)	0.0284 (3.449)
MGT (IV)	7.885 (3.265)
TRAINING (IV)	.725 (1.120)
METAL	-.488 (2.042)
CONSTANT	-8.766 (3.430)
Pseudo-R^2	.089
Observations	173

Surprisingly, our results suggest that assignment of more workers to environmental monitoring and enforcement has no significant effect. However, plants which have adopted ISO-14000 procedures perform significantly better, even after simultaneity effects are purged.

Our results also suggest that mainstreaming works: Better environmental performers assign environmental responsibility to general managers, and they provide environmental training to non-environmental workers as well as environmental specialists. Interpretation of this result depends on one's behavioral model. We believe that firms are experimenting with a variety of approaches because environmental management is a new field in Mexico. However, we recognize that some additional assumptions would make our results consistent with a model of profit-maximizing choice among well-known techniques. As we noted previously, environmental specialization in training and management may be cost-effective for plants whose environmental problems are technically complex, concentrated at a few points, and separated from standard production processes. If one assumes that abatement costs are significantly higher for such plants, then profit

[5] See Dasgupta, et. al., 1996.

maximization dictates both more specialized management and lower average compliance rates. The result is a negative association between specialized management and compliance, but it has nothing to do with experimentation.

Are abatement costs really higher for such plants? A priori, it is possible to construct arguments for and against this proposition. We cannot test it with our data, and we are not aware of any empirical work on the issue.

Among the other variables in the complete compliance equation, only one sector dummy (METAL) has any significant effect. Once we control for management effort and degree of mainstreaming, we find that worker education, scale, and technology vintage do not significantly affect compliance. Of course, scale and worker education have indirect effects through their impacts on ISO 14000 procedures and mainstreaming. By contrast, technology vintage has no effect in either stage of the analysis. This runs strongly counter to the conventional wisdom, but the result seems reasonably robust. As Table 9 shows, our sample plants exhibit wide variation in the proportion of equipment installed since 1990. If there were a significant effect, we would expect to observe it in such a highly-varied sample.

Exogenous Determinants of Environmental Performance

The results in Tables 7 and 8 can be combined to yield some tentative conclusions about the exogenous determinants of environmental performance in Mexican industry. Through their effect on adoption of ISO 14000 procedures, we find significant effects for plant size, multi-plant status, educated workers and recent experience with regulation. A few of our exogenous variables also affect performance through their impact on mainstreaming. Plant size has countervailing effects in this context: It encourages generalized environmental training, but it also encourages specialized management. Experience of recent regulation has a perverse, albeit weak, effect on performance through encouragement of specialized management. Firms which are publicly traded, on the other hand, are significantly more likely to train non-environmental workers, with positive consequences for environmental performance.

Table 9: Proportion of plant installed since 1990

	Frequency	%
0-20%	124	53.9
21-40%	33	14.4
41-60%	26	11.3
61-80%	13	5.6
81-100%	34	14.8

6. Implications

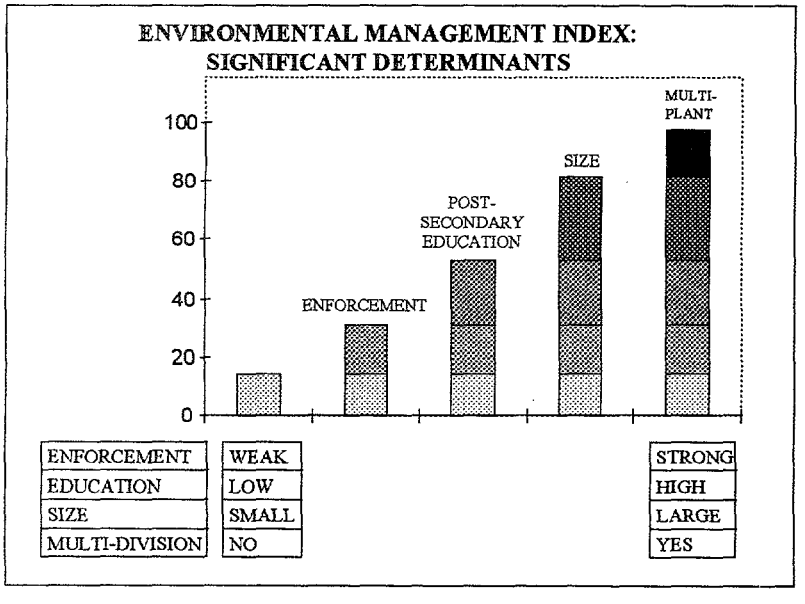
Among the significant determinants of environmental performance, we are interested in identifying the most influential variables. To measure relative impacts, we predict levels of environmental management and compliance using low- and high-range values for the significant exogenous variables. Table 10 summarizes the values used for prediction.

Table 10: Simulation Values for Exogenous Variables

	SIZE	PUBLIC	EMPHIGH	MULTIDIV	RULES	METAL
Low	1	0	0	0	1	0
High	3	100	100	1	5	1

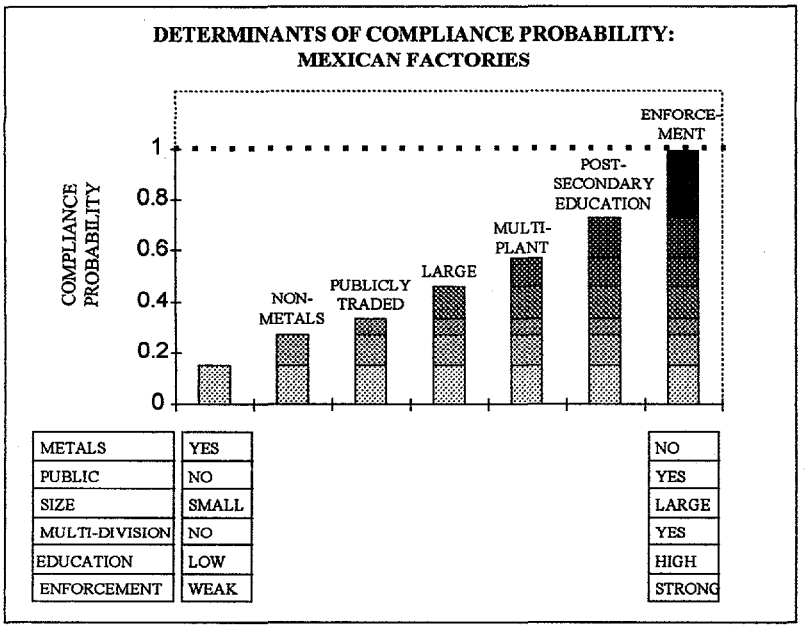
Figure 1 presents results for the determinants of EMS, the environmental management index. On a scale of 0 to 100, we find that 'worst-case' plants have a predicted index value of 14. Such plants are small; not part of multi-plant firms; have no employees with post-secondary education; and have experienced very weak regulation, if any. As we substitute high values of the exogenous variables, the score improves progressively: by 17 for strong regulation; 22 for 100% post-secondary education; 29 for large size; and 16 for ownership by a multi-plant firm. Plants with all the high-level characteristics have a predicted index value of 98: nearly complete implementation of an ISO 14000-type environmental management system. Although regulation clearly makes a difference, our results suggest that a very large proportion of the difference between firms with weak and strong EMS implementation is explained by education and scale (at the plant and firm levels).

Figure 1: Relative Impact on Environmental Management



The impacts of exogenous variables on EMS are of strong interest, because our results suggest that internal management strategy makes a substantial difference for environmental performance. However, a larger set of exogenous variables has an impact on compliance probability through the two training variables. Figure 2 summarizes the total impact of the exogenous variables on compliance. Within our sample, 'worst-case' plants have a predicted compliance probability of about 12%, while 'best-case' facilities have a 99% probability. Figure 2 illustrates the incremental contributions: Production in non-metals sectors adds 12%; all shares publicly traded adds 6%; large size 13%; multi-plant status 11%; post-secondary education 16%; and strong regulation 26%. For compliance, strong regulation emerges as the most important variable.

Figure 2: Relative Impact on Compliance Probability



7. Summary and Conclusions

In this paper, we have used new survey evidence to analyze the effects of regulation, environmental management policies, and plant/firm characteristics on the environmental performance of Mexican factories. The results of our two-stage estimation exercise are simple, clear, and relatively consistent. We can summarize our principal findings as follows:

(1) **Process is important.** Plants which institute ISO 14000-type internal management procedures exhibit superior environmental performance.
(2) **Mainstreaming works**. Environmental training for all plant personnel is more effective than developing a cadre of environmental specialists; assigning environmental tasks to general managers is more effective than using special environmental managers.

(3) **Regulatory pressure works.** Plants which have experienced regulatory inspections and enforcement are significantly cleaner than their counterparts.
(4) **Public scrutiny promotes stronger environmental policies.** Publicly-traded Mexican firms are significantly cleaner than their privately-held counterparts.
(5) **Size matters.** Large plants in multi-plant firms are much more likely to adopt policies which improve environmental performance.
(6) **OECD influences don't matter.** Analyses of pollution control in developing countries generally assume that plants linked to the OECD economies have superior environmental performance. However, we do not find a significant association for any OECD linkage: multinational ownership, trade, management training, or management experience.
(7) **New technology isn't significantly cleaner**. We find no evidence that plants with newer equipment have better environmental performance, once other factors are accounted for.
(8) **Education promotes clean production.** Plants with more highly-educated workers have significantly greater environmental management effort and performance.

Our results have some interesting implications for the World Bank and other development assistance institutions. The significance of our regulatory variables underscores the importance of strengthened enforcement, which has been a traditional focus of technical assistance projects. Stricter enforcement raises the *price of pollution* and provides an important incentive for pollution reduction. However, our results also highlight the potential of programs which promote more effective environmental management and training within plants. Such programs can increase the *elasticity of industry's response* to regulation, and may in some cases provide very cost-effective complements to stricter enforcement.

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APPENDIX 1

Sample Distributions of Model Variables

Ownership: Publicly Traded/Privately Held

	Number	%
Private	124	59.6
Mixed	14	6.7
Publicly Traded	70	33.7

Ownership: Mexican/Multinational

	Number	%
Mexican	209	90.9
Multinational	21	9.1

Firm Type

	Number	%
Single Plant	105	46.7
Multi-Plant	125	53.3

Reported Influence of Regulation

	Number	%
Low	35	14.8
Medium	37	15.7
High	164	69.5

Prior Experience of Enforcement

	Number	%
No	38	16.7
Yes	189	83.3

Worker Education

% with Secondary Education	Number	%
0 - 25	71	33.2
26 - 50	74	34.6
51 - 75	26	12.1
76 - 100	43	20.1

Distribution of Shipments to OECD, Mexico and other

	Mean	SD	Max	Min
% of sales to OECD	14.0	25.2	100	0
% of sales to Mexico	80.8	29.3	100	0
% of sales to Other	5.2	12.5	100	0

Managers with Secondary Education as the Highest Level of Education

Highest level of education	**Frequency**	**%**
Secondary	4	1.7
Other	226	98.3

OECD Experience of Person in Charge

	Frequency	%
Without experience	172	72.6
With experience	65	27.4

APPENDIX 2

ISO 14000 Standards for Environmental Management[6]

Certification by the International Standards Organization (ISO) is considered important by many firms seeking rapid growth in the international marketplace. Many leading multinationals attach a strong preference to subcontractors which have satisfied ISO requirements, in particular the ISO 9000 series of quality control standards. Although only published in 1996, the ISO 14001 series of standards for Environmental Management Systems (EMS) has already attracted significant attention from industry.

Within the ISO 14001 series, some standards are still under negotiation. However, the EMS standard has been finalized, and requires organizations seeking certification to take the following steps:

- An initial review by management to identify environmental issues of concern (e.g. excessive use of polluting inputs; the potential for a serious environmental accident);
- Establishment of priorities for action, taking into account factors such as local environmental regulations and potential costs;
- Establishment of an environmental policy statement, to be signed by the CEO, which includes commitments to compliance with environmental regulations, pollution prevention and continuous improvement;
- Development of performance targets based on the policy statement (e.g. reduction of emissions by a set amount over a defined period);
- Implementation of the EMS, with defined procedures and responsibilities;
- Implementation reviews, performance measurement, and management audits.

Although new, ISO 14001 is already having a significant impact on the environmental stance of firms in both industrial and developing countries. In Europe, businesses are rapidly adopting an Eco-Management and Audit Regulation (EMAR) established by the European Union, which incorporates the ISO 14001 principles, plus requirements that firms comply with environmental legislation and publicly report their environmental performance. To remain competitive in Europe, many Japanese companies are aggressively pursuing ISO 14001 certification, and a number of US firms have followed suit.

ISO 14001 is also receiving significant attention in developing countries. Early in 1997, Altos Hornos de México was the first Mexican company to be certified to ISO 14001 for part of its operations. Since then, it has been followed by a number of major Mexican facilities, both domestic and foreign-owned. The interest in EMS has extended to Mexico's Environment Ministry (SEMARNAP), which has incorporated a voluntary EMS into its regulatory system. To promote adoption, SEMARNAP will establish a set of

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[6] Our thanks to Paul Martin for extensive comments on a previous draft of this Appendix, and to Richard Wells of The Lexington Group for very useful discussion of ISO 14001 standards.

incentives such as accelerated depreciation on environmental equipment and eligibility for simplified licensing procedures. In Asia, both Indonesia and Philippines intend to incorporate ISO 14001 elements into their new programs for public disclosure of firms' environmental performance.

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